Stream Macrobenthos at Yorktown Battlefield:

Inventory and Analysis

Prepared for:

National Park Service
Colonial National Historic Park
Charles D. Rafkind
Natural Resource Manager

Prepared by:

Gregory M. Capelli
Assoc. Prof. Biology
College of William & Mary
Williamsburg, VA 23187

July 2000 (REVISED)

Table of Contents

Executive Summary

We report here the results of stream macrobenthos and related sampling conducted at Yorktown Battlefield during 1997-98. Data provide a beginning, but substantive, inventory of organisms associated with this community, and also allow a general interpretation of water quality in the area. As part of our analysis, we have included data collected by the Virginia Department of Environmental Quality at a site on Baptist Run, within the Battlefield's boundaries. Overall, 53 families of macrobenthos were found. However, water quality interpretation from macrobenthic community composition is complicated by two considerations: 1) little reference-site information is available (i.e., community composition under undisturbed conditions) for the coastal plain, and 2) general coastal plain stream habitat, involving slow flows and silty substrates, is not well-suited to many groups of benthos that traditionally have been considered among the most important indicators of good water quality (e.g., stoneflies, caddisflies, and mayflies). Nonetheless, based on a comparison with an undisturbed preserve on the William & Mary campus, and on the presence of certain specific organisms at the Battlefield, we conclude that water quality remains high in the area.

Consistent with what is believed to be the historically natural situation, Battlefield streams are dominated by a single species of crustacean, an amphipod known as *Gammarus pseudolimnaeus* in the family Gammaridae. This species is of special interest in southeastern Virginia, because populations in this area are far disjunct from the normal range, which encompasses the Great Lakes and upper Mississippi drainages (see footnote 1 in text for further discussion). This single species typically accounted for 50% or more by number of all macrobenthic individuals collected. Only 6-7 other families were even moderately abundant, and beyond these all of the remaining families in total accounted for only about 20% of the individuals collected.

G. pseudolimnaeus is believed to occur only under undisturbed or minimally-impacted conditions, and therefore its widespread presence throughout the Battlefield area suggests that water quality is generally good. In fact, the Battlefield area may now be the largest area in Virginia with continuously-distributed populations of this species. Also of special note is the caddisfly family known as the Glossosomatidae, which was found only in one small area (Washington Springs). This family, which is among the most sensitive of any to disturbance, is believed to be extremely rare in the coastal plain.

Overall, the work reported here helps provide important reference information for future macrobenthic collecting and interpretation in the coastal plain. Also, given the apparently natural community assemblages present at the Battlefield, the area has much promise as a research site for addressing a variety of questions involving the factors that control macrobenthos distribution.

Given the absence of any apparent significant degradation at the sites sampled, current management practices involving maintenance of the area in a combination of natural and semi-natural conditions appear to be appropriate.

Introduction

The primary purposes of this work at the Yorktown Battlefield were to provide an inventory of freshwater stream macrobenthic organisms, and to use the results to assess general water quality within the area. There are a number of interrelated considerations relevant to these purposes. For several decades macrobenthos analysis has been a major tool for assessing freshwater stream quality. In effect, the macrobenthic community is a monitor that integrates the impact of both short-duration and more-continuous environmental conditions. In undisturbed streams macrobenthos are typically numerous with high taxonomic diversity. Although often difficult to identify to species, most can be identified to family relatively easily, and this level is generally sufficient for characterizing water quality reasonably well. Various "metrics" (mathematical formulas) currently exist for quantifying macrobenthic data; relatively simple but useful features of some of these include the following considerations.

At both the species and family level there are wide variations in tolerance to disturbance. As a result, analysis and interpretation can be made based on broad indexes (e.g., total taxa diversity) as well as presence/absence of specific taxa. As a basic aid in certain kinds of such analysis, a system has been developed whereby a given type of organism (at either the species or family level) is assigned a "tolerance value" on a scale of (typically) 0-10, with lower values indicating lower tolerance to degradation and higher values indicating greater tolerance. In this report, all tolerance values are those that have been established at the family level for the State of Virginia.

Three major taxonomic groups are of special note in assessing water quality. All are orders of insects in which the immature, larval stages are aquatic: the Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). Within each order of this "EPT" group are numerous families with variation in tolerance values, and further variation at the species level. However, the majority is moderately to extremely intolerant of disturbed conditions, with tolerance values of 4 or less. Plecoptera are generally the most intolerant; all Virginia families have a tolerance value of 2 or less, with the majority at 0 or 1. The presence of a well-developed EPT community generally has been considered evidence of high water quality.

A fundamental need in assessing macrobenthos stream data is knowledge of natural assemblages in undisturbed conditions. Community composition may vary significantly, even under pristine conditions depending on many variables, including substrate type, current speed, and water chemistry. Most biomonitoring work, and the "principles" derived from that work, involves streams with significant areas of relatively high current speed and firm, gravelly substrates; these are also the areas preferred by a high percentage of EPT organisms. However, stream conditions vary substantially among geographic regions, and it is therefore important that reference areas be identified. These are sites similar to those being sampled that are thought to be as undisturbed as possible, providing a base against which a given set of findings can be judged.

This is an important consideration for the work described here, because relatively little reference information is available for the coastal plain area of Virginia, regarding either types of organisms to be expected or other aspects of community structure. However, over the past few years the Virginia Department of Environmental Quality has sampled a site on Baptist Run within the Battlefield area. This sampling is part of a state-wide program under which nearly 200 sites are sampled twice yearly (spring and fall) for biomonitoring interpretation of water quality. According to Tony Silvia, a Regional Biologist for DEQ who is responsible for sampling in southeastern Virginia, the Baptist Run site was chosen because it appeared to be suitable as a reference area for coastal plain streams of similar type, i.e., it appeared to be relatively undisturbed and presumably exhibited a natural assemblage of organisms that could serve as the "expectation" for other habitats. Because of the relevance of this work to the purposes of this report, we begin with a summary and analysis of the DEQ data; this provides not only important inventory information, but also a valuable comparative backdrop for our results from other areas within the Battlefield.

Summary and Analysis of State of Virginia Biomonitoring Data

The Battlefield site used by DEQ is located on Baptist Run at the Highway 637 (Crawford Rd.) crossing (equivalent to our Site 11 indicated on the map in Figure 1, as described later). The sampling procedure in this area is based on an EPA-approved “rapid bioassessment” protocol, and involves the use of a standard 30-cm (12-inch) wide D-frame collecting net, with a mesh size of about 700 microns. Over approximately a 100-m distance upstream from Crawford Rd., the net is used to take 20 "bank samples." These entail collecting in vegetation or leaf litter near the bank, where macrobenthos tend to be most common and diverse. Raw data consist of numbers of individuals in each family found, plus information on oxygen, temperature, pH, and conductivity (an index to the amount of dissolved material in the water). By design, this method is intended to standardize and minimize the necessary effort for meaningful collecting; it is not designed to routinely collect rare types of organisms or those not easily swept into a net (such as those burrowing in the substrate, or clinging tightly to sticks).

We have obtained the DEQ records for eleven samplings at Baptist Run, from Spring 1993 through Spring 1998. This record is extremely valuable in providing basic natural history information for the area as well as information about likely community structure at other sites.

DEQ data indicate physical/chemical variables at Baptist Run in the following ranges: dissolved oxygen 8.5-11 mg/l, pH 7.3-7.9, and conductivity 360-420 μmhos. All are within normal, expected ranges, and should not negatively affect the macrobenthic community.

A range of 9-23 families was collected in individual seasonal samplings at Baptist Run, with a mean of about 14. Overall, a total of 40 families were found (Table 1). This general level of diversity, both in individual samples and overall, is very similar to that of several small streams within the College Woods preserve on the campus of the College of William & Mary. These streams, with overall family diversity of 38-42, are believed to be minimally impacted. Thus, a similar value for Baptist Run suggests that its use by DEQ as a reference area is appropriate. However, as further analysis indicates, coastal plain streams--even when relatively undisturbed--have macrobenthic communities that differ significantly from those expected in clean-water habitats in other areas.

Although 40 taxa were present in total, the single family Gammaridae (amphipods) was by far the dominant component of the community. Although amphipods were not identified to species by DEQ and we have not examined their specimens, our work has confirmed that all Gammarid individuals at this location are (near) *Gammarus pseudolimnaeus*[1]. Overall, DEQ collections totaled 1320 individual organisms. Of these, 693 (53%) were G. *pseudolimnaeus,* which averaged about 63 individuals/sample (Table 2). Four families comprised, respectively, of snails (Physidae), small clams (Sphaeriidae), damselflies (Calopterygiidae), and dragonflies (Gomphidae) accounted for most of the remaining organisms at the site. The other 32 families accounted in total for only 20% of the organisms collected, with an average of only 0.7 individuals/family/sample. Several of these were represented by only a single individual collected over the eleven samplings, and most involved no more than 5-10 individuals found during only 1-3 samplings.

The EPT group, usually considered to be an important indicator of high-quality water as discussed earlier, was notably sparse, with no EPT families among the common organisms. Among Plecoptera (stoneflies), which is the EPT group with collectively the least tolerance for disturbance, only two families were found; of these, the Nemouridae was represented by a single individual and the Perlodidae by 7 individuals found in only two samples. Among mayflies, the Baetidae were represented by 8 individuals in 5 samples, the Heptageniidae by 8 individuals in 3 samples, and the Leptophlebiidae by only two individuals in two samples. The caddisfly family Limnephilidae was the most common of any EPT group, but with only 16 individuals among 7 samples. The other three caddisfly families (Hydropsychidae, Leptoceridae, and Rhyacophilidae) were each represented by only a single individual.

In many areas, a situation broadly similar to this (i.e., dominance by a single family and minimal representation of EPT groups) would probably be associated with a significantly impacted habitat. Also, the groups Physidae and Sphaeriidae, which were the next most abundant after amphipods, are commonly found in disturbed areas (consistent with their tolerance value of 8). However, the specific amphipod present (*G. pseudolimnaeus),* the occurrence of certain other groups and other considerations indicate that the habitat is probably of reasonably high quality, as follows.

As noted earlier, the overall taxa diversity is similar to that occurring in other streams in the area thought to be undisturbed, specifically some on the William & Mary campus. The community similarity extends further: in the campus streams *G. pseudolimnaeus* is by far the

[1] *Gammarus pseudolimnaeus* is a species known previously from the Great Lakes and upper Mississippi River drainages, far disjunct from southeastern Virginia. The individuals collected at the Yorktown Battlefield, and in various other places within the James and York River drainages, appear to be identical to *G. pseudolimnaeus*, based on published descriptions and identification keys. Dr. John Holsinger of Old Dominion University, an authority on amphipods, confirms this observation, but suggests use of the proper formal terminology "(near) *Gammarus pseudolimnaeus*" because the synonymy of our species with *G. pseudolimnaeus* has not been unequivocally confirmed. For convenience, however, we will refer to our species simply as *Gammarus pseudolimnaeus* within this report.

dominant organism, with Physidae next in abundance. Sphaeriidae, Calopterygiidae, and Gomphidae, which are the next most common families in Baptist Run, are likewise routinely found in the campus streams. Among EPT groups, the Heptageniidae are more common in the campus streams than the DEQ data suggest for Baptist Run, but this may be due to the fact that these organisms generally cling to sticks and may not be captured readily by the DEQ's net method. Distribution of other groups (involving only very small total numbers of individuals that are typically not encountered in any given single sample) is similar.

Although EPT representatives are not common in Baptist Run, some of the other families present have been associated previously only with good habitat (as reflected in their assigned tolerance values), and their presence therefore infers such conditions. This is most notably the case with *G. pseudolimnaeus*. At the family level Gammarid amphipods have an assigned tolerance value of 4, suggesting an association with fairly good water quality but not requiring extremely high quality. However, in recent years we have developed good evidence that Gammaridae differ significantly in tolerance at the species level. This is especially the case regarding the two common Gammarid amphipods in this area, *G. pseudolimnaeus* and *G. fasciatus*, for which we have developed the following hypotheses based on our observations in other areas. *G. pseudolimnaeus* occupies habitats with a substantial range of physical/chemical conditions, but is only found in areas not significantly degraded. *G. fasciatus* appears to be competitively inferior to *G. pseudolimnaeus* but able to tolerate greater disturbance. Thus, where conditions are suitable for *G. pseudolimnaeus*, this species displaces *G. fasciatus*; under less favorable conditions, however, *G. fasciatus* fills the void left by the absence of *G. pseudolimnaeus*. In severely disturbed areas, no Gammarid amphipods are present.

The above relationships should be considered hypothetical, because the exact negative factors to which *G. pseudolimnaeus* is sensitive, and the competitive mechanisms that exist between this species and *G. fasciatus*, are not known. Also, we have some evidence that there may be differences between the two species in their tolerance of natural conditions; for example, *G. fasciatus* may tolerate somewhat warmer temperatures and siltier substrates. In brief, *G. pseudolimnaeus* appears to be associated only with good conditions, although its absence does not necessarily infer degraded conditions.

A major factor limiting EPT groups in Baptist Run is probably the lack of a firm, gravelly substrate typical of habitats where these families are most common. Unfortunately, there are only a few families from other groups that are commonly associated with other types of substrates and which have also been associated with high-quality water. Among these are the three dragonfly families found at Baptist Run (Aeshnidae, Cordulegastridae, and Gomphidae; see Table 1), which have tolerance values of 3 or less. Most notable among these is the Gomphidae, with a tolerance value of 1, for which 25 individuals were found in a total of 9 samples. These dragonfly larvae typically burrow into the sandy substrate, and are often missed in collections. Therefore, the numbers seen here, though relatively small, probably indicate a sustained, permanent population.

In summary, use of Baptist Run as a reference site for other relatively small coastal plain streams seems justified. Collections there also confirm the significant differences in community composition between coastal plain streams and those in other areas, which are not necessarily related to differences in disturbance or degradation.

The DEQ data, in combination with our data from other locations such as the College Woods, begin to construct a fairly clear picture of natural assemblages in freshwater streams in this area. This information also guided our expectations for other streams at the Battlefield. In brief, we predicted that most other sites should be dominated by *G. pseudolimnaeus,* with only relatively small numbers from other groups.

General Observations

We conducted a general visual inspection of the Battlefield area in early March 1997. Streams ranged from very small first-order spring-fed flows, portions of which appeared to be intermittent, to larger third-order habitats (e.g., Beaverdam Creek). Two major drainage systems were involved, with some streams flowing to the York River and others to the James River. Habitat appeared to be in generally good condition, with vegetation present along most banks and no obvious indications of ongoing major disturbance. Problems with excess nutrients (one of the most common effects of human activity) were evident only in a small area immediately above the ford at the Washington Springs flowage, where a large amount of the algae *Spirogyra* was present in pools. Substrate was generally typical of coastal plain habitats, consisting primarily of sand with varying amounts of silt, leaf litter, and sticks/snags. Small amounts of macrophytic vegetation were present in a few areas[2]. Firmer substrate in the form of gravel and larger rocks was almost completely lacking. Long stretches of Great Run and Baptist Run, on the basis of their uniform bank structure and apparent absence of natural bends, appeared to have been channelized at some time and thus were probably exposed to significant disturbance. No information is available on when this occurred, but the apparent age of bank vegetation in these areas suggests that it was at least several decades ago.

Wormley Pond, the only lake-type habitat at the Battlefield, appeared to be a typical highly eutrophic body of water; many of the shallower areas were choked with excess growth of macrophytic vegetation, particularly *Ceratophyllum.*

Amphipods were apparent in most areas, and brief collecting and identification indicated that *Gammarus pseudolimnaeus* was common.

General Chemical Conditions

We conducted a basic chemical survey of the area during March 13-15, 1997 by measuring temperature, oxygen, conductivity, and pH at 20 sites chosen to reflect the diversity of habitats

[2] Marsh conditions (i.e., emergent herbaceous vegetation in standing water) occur in various areas. For example, the lower portion of Ballard Creek opens into a freshwater marsh before becoming brackish; there is also marsh habitat toward the lower portion of Beaverdam Creek. Swamp habitat (trees in standing water) of varying sizes also occurs, often in close proximity to streams. These types of habitat are not included here.

present. Equipment consisted of a YSI Model 57 temperature/ oxygen meter and a YSI Model 33 conductivity meter, both used in the field, and a Fisher Model 5 pH meter, used in the laboratory. Oxygen, measured in units of mg/l, is crucial to macrobenthic communities. For various reasons oxygen often declines under disturbed conditions, and sensitivity to reduced oxygen is often the key consideration causing a given species to have a low tolerance value. The amount of oxygen that water can hold varies inversely with temperature; therefore, it is also useful to report oxygen values in terms of percent saturation for the given temperature. Conductivity is a general measure of the amount of dissolved solids in the water, expressed here in units of µmhos. Freshwater values in the coastal plain typically range from near 0 to about 700 µmhos, corresponding to a total dissolved solids level ranging up to about 500 mg/l.

Following is a list and brief description of the location of each site (see map in Figure 1; "red" and "yellow" below refer to the tour route designations used on this map).

1. A very small unnamed seep located immediately adjacent to the red tour road, approximately 500 m above the north arm of Wormley Pond, into which the seep flows. (Seep not shown on map).

2. The north arm of Wormley Pond, lying immediately adjacent to the red tour road.

3. Wormley Pond at the dam.

4. The small unnamed tributary of Wormley Pond, beginning near Cook Road and flowing into Wormley Pond from the southwest; sampling location was approximately 150 m downstream from Cook Road.

5. The small unnamed tributary of Wormley Pond, flowing from the northwest; sampling location was approximately 200 m above Wormley Pond.

6. Beaverdam Creek immediately south of the yellow tour road.

7. A small unnamed tributary of Beaverdam Creek located approximately 300 m north of the yellow tour road, flowing from the west; begins as a discreet spring from a small embankment; total length approximately 200 m; sampled in small pool at spring origin (spring and flow not shown on map).

8. Unnamed tributary of Beaverdam Creek beginning near Surrender Field; located approximately 500 m north of the yellow tour road, flowing from the east; sampled 10 m above its mouth.

9. Unnamed stream at the ford leading into Washington Springs area; sampled immediately above ford.

10. Washington Springs; sampled in the small pool where the spring closest to the parking area emerges from the ground (spring not shown on map).

11. Baptist Run immediately west of Crawford Rd. (Route 637). This is the same site monitored by the State DEQ, as described above.

12. Baptist Run immediately east of the yellow tour road.

13. Upper area of Great Run immediately west of where it crosses the west side of the loop in the yellow tour road (French Encampment Area)

14. Small unnamed tributary of Great Run, joining Great Run immediately below Site # 13 above, on west side of loop in yellow tour road.

15. Upper area of Great Run immediately east of where it crosses the east side of the loop in the yellow tour road (French Encampment Area).

16. Great Run immediately east of Crawford Rd. (Route 637).

17. Great Run at yellow tour road, approximately 200 m west of Route 17.

18. Small unnamed tributary of Ballard Creek, flowing north from the trailer park located on Route 238; sampled approximately 120 m from trailer park boundary.

19. Ballard Creek at site approximately 150 below western boundary of apartment complex on Route 238.

20. Unnamed stream crossing Colonial Parkway approximately 100 m south of Route 238, flowing toward Victory Center; sampled approximately 20 m east of Parkway.

Results of the general chemical survey are listed in Table 3. Broadly, conditions appeared to be normal, with all parameters within typical and expected ranges.

Conductivity values generally ranged from about 250-500 µmhos, which can be characterized as within the moderate to relatively high range for freshwater. This is typical of other freshwater habitats in the area, and reflects in part the large amount of dissolvable calcareous materials associated with the local geological conditions. Regarding community structure, this range is appropriate for a high diversity of macrobenthos, including amphipods. Three sites (13, 14, 15) had lower conductivity values. Site 14 is a very small tributary of Great Run, entering the latter on the west side of the loop in the French Encampment area. The conductivity value here of only 30 µmhos indicates very dilute water that probably would prevent at least some macrobenthos, including *Gammarus* amphipods, from inhabiting the area. Also, at other times later in the study period, this stream was dry. This and the low conductivity suggest that it depends primarily on fairly direct rainfall input.

Great Run proper in this area (Sites 13 and 15, at values of 110 and 150 µmhos), was also somewhat lower in dissolved materials than were most other locations, but within a range satisfactory for most benthos.

Fresh water with moderate to high levels of dissolved materials usually contains significant amounts of chemical buffers (typically carbonates and bicarbonates associated with calcium) that result in a pH in the range of 7-8. As expected, all Battlefield sites were within this general range except #14 where pH was 6.5. This lower value is consistent with our observation of other low-conductivity streams in this area in which little buffering material is present.

Oxygen at most sites were in the range of 8-10 mg/1, with saturation values of 75-90%. This should be satisfactory for most benthos. Some sites had lower values, but these appeared to be associated with natural conditions rather than with disturbance. For example, Sites 1 and 18 were very small seepage flows with a large amount of organic material in the form of leaf detritus; the latter probably resulted in a proportionally high oxygen demand. Lowest oxygen values were found at sites 7 and 10, at the emergence points of springs. Groundwater is typically low in oxygen, and the reduced level at these sites is normal. Oxygen level increased quickly downstream from these sources.

Overall, there appeared to be no major disturbances (other than the very eutrophic conditions in Wormley Pond, described earlier on the basis of visual observations). In many locations, conditions appeared to be generally similar to those at the Baptist Run site sampled by the DEQ (our Site 11), and our expectation was that community structure would be similar.

Macrobenthos Collections: Sites

Six general areas were selected for the main focus of macrobenthic collecting, interpretation, and comparison with DEQ data. These were chosen to provide representative sites where benthic communities were expected to be reasonably well developed, but with some variation in certain aspects such as size, substrate type, and apparent current speed. General descriptions of each are as follows:

Washington Springs. The area extending from the springs proper, including the stream formed by their confluence, and continuing to the ford. This corresponds to the area from Site 10 to Site 9 in Figure 1. In the immediate area of the springs, substrate consists of pebbles and shell fragments, unlike the silt and sand in most other areas of the Battlefield.

Baptist Run. The area corresponding approximately to Sites 1 l and 12 in Figure 1, continuing approximately 300 m downstream from Site 12. The upper portion includes the area sampled by DEQ.

Great Run. The area corresponding to Site 17 in Figure 1, continuing approximately 200 m upstream and downstream from the tour road crossing.

Beaverdam Creek. The area corresponding to Site 6 in Figure 1, continuing approximately 300 m upstream from the tour road, and 100 m downstream.

Ballard Creek. The area corresponding to Site 19 in Figure 1, encompassing a 600 m distance running north of, and approximately parallel to, the apartment complex boundary.

"Wormley Creek." The area corresponding to Site 5 in Figure 1, beginning approximately 400 m above Wormley Pond and continuing to the Pond. This flow has no official name; we designate it "Wormley Creek" here for reference convenience. This area was chosen in part because the upper portions appeared to be intermittent, but contained several large pool-type habitats where organisms less-associated with streams or significant current might be found.

Washington Springs, Baptist Run, Great Run, and Beaverdam Creek are in the James River drainage; Ballard Creek and Wormley Creek are in the York River drainage.

Macrobenthos Collections: Chemical Conditions at Sites

During October 1997, these six sites were sampled for various chemical constituents, as listed in Table 4. Samples were taken at approximately the midpoint of each area. Temperature, oxygen, conductivity, and pH were measured with the equipment described earlier. Other chemical parameters were determined using Hach Chemical Company equipment and associated procedures, involving either spectophotometric analysis with a Model 2010 spectrophotometer or titrations with digital titrators; all values reported here are means of two samples. As expected, all parameters were within normal ranges for fresh water generally and for this geographic area. All sites exhibit distinctly "hard" water, with calcium in particular at high levels. The key nutrient phosphorus, which can cause excess production of algae and macrophytic vegetation, was at relatively low levels except in Ballard Creek. In no area, including Ballard Creek, was there any evidence of excess productivity. The excess growth of Spirogyra near the Washington Springs ford, observed earlier in the year, was not evident at this time. Broadly, general chemical conditions did not appear to be limiting at any site to the development of a natural macrobenthic community.

Additional data, not reported here, were taken for these same parameters periodically throughout the course of this study. Normal variation occurred involving seasonal temperature differences and fluctuation in other parameters related to rainfall, flow level, etc. However, in all cases the variables remained within normal and expected ranges.

Macrobenthos Collections: Methods

Macrobenthos were collected primarily during two periods: from mid-October through mid-November 1997, and at the same time during 1998. An additional sampling period was planned for March 1998, but heavy rains immediately prior to the available time resulted in near-flood conditions. During this time only limited sampling could be done, in areas such as the uppermost portion of Washington Springs and in Wormley Creek, where flows are sustained primarily by groundwater with minimal impact from surface run-off.

Macrobenthos were collected using a variety of methods. Where possible, a procedure similar to that used by the DEQ was employed, i.e., use of a standard 30-cm wide, 700 micron mesh, D-frame net to collect "bank" samples. This method, however, is not fully satisfactory for obtaining as much information as possible in the type of streams involved here. First, "bank" areas near the edges often have little structure or shelter potential, in the form of vegetation or other kinds of habitat complexity. The most common available habitat, other than bare stream substrate, was usually leaf detritus in varying stages of decomposition. Depending on exact stream hydraulics at a given site, this might occur in any area of the stream. Secondly, some of our sample sites (e.g., the upper areas of Washington Springs) were simply too small to use a relatively large net effectively. And finally, there are various types of organisms that are not likely to be collected in representative numbers by net sampling. These include those that tend to adhere strongly to sticks and logs (such as mayflies in the family Heptageniidae, various Trichoptera, the most common members of the Corydalidae, and Gordioida), or those that burrow into the substrate (such as various Oligochaeta and Diptera, and the dragonfly family Gomphidae).

We therefore used a variety of collecting methods. Within each site, during each of the two fall sampling periods, we collected 20 samples using either, or a combination of, the standard D-frame net described above or a 15-cm diameter sieve of approximately the same mesh size as the net; the latter was generally used to sample small amounts of detritus that were loaded by hand into the sieve. We focused on areas that appeared most likely to yield organisms, such as detritus accumulations or vegetation. In addition, within each area, we collected and searched sticks and logs by hand; this entailed two individuals spending approximately 15 minutes each in this process. Sediments were also sampled in each area by taking 8 samples to approximately an 8-cm depth using either the D-frame net or the sieve. Organisms were preserved immediately in 70% ethyl alcohol.

All organisms collected were included in the data analysis and interpretation described below, except as follows. Older *G. pseudolimnaeus occupy* the surface of the substrate, where they commonly occur in the open but are most abundant in leaf litter. Young individuals, however, appear to occupy a different niche, burrowing into the substrate where they typically occur at extremely high densities. The sediment samples described above often yielded hundreds of small G. *pseudolimnaeus,* with lengths of < 4-5 mm. We did not include these in our collections or analysis. Thus the *G. pseudolimnaeus* information presented below is based on individuals collected primarily with the other methods, involving individuals generally > 5 mm in length.

There is as described above, necessarily, a great deal of variation in the types or combinations of methods used in different areas, and in the variation inherent in each method (e.g., it is difficult to hold constant or to determine quantitatively the exact "amount" of stick area sampled). Because of this, we do not attempt here detailed quantitative comparisons among the various areas. A primary purpose, which these methods should support, was to maximize inventory information. We believe these methods ensured collection of all common taxa as well as many rarer ones. Additionally, the information serves well to allow broad comparative characterization of water-quality considerations, as described below.

Macrobenthos Collections: Results and Interpretation

For all sampling in all six areas combined, a total of 2170 individuals involving 39 families was found, as listed in Table 5. Our results are broadly consistent with those of DEQ for the Baptist Run Site, as described in the summary statistics at the bottom of Table 5, and in Table 6. At each site, Gammaridae (amphipods) consisting entirely of *G. pseudolimnaeus* were by far the numerically dominant organism, ranging from 38% to 69% of individuals collected; the mean of 51% for the six stations, and the overall value of 48% for all samples combined (Table 6) are close to the 53% value for the DEQ data (Table 2). For Physidae (a snail) , the second most common organism, both the site mean and the overall value were about 12%, close to DEQ's 11%. And in our collections as well as DEQ's, the three next most common organisms were the Sphaeriidae (fingernail clams), Calopterygiidae (a damselfly), and Gomphidae (a dragonfly), although percentages and rank varied somewhat (Tables 2 and 6).

In addition to these last three groups above, we found three others of similar modest representation: Limnephilidae and Glossosomatidae (both caddisflies), and Chironomidae (midges), as indicated in Table 6. A few Limnephilidae were found by DEQ, but these are probably underrepresented in their samples because the common representative of this group at Yorktown, which lives in a case made of vegetation, is found almost exclusively attached to sticks. All individuals in our sample were collected by hand from sticks; the net collecting method used by DEQ probably was less likely to dislodge and capture this group.

The Glossosomatidae build cases made of small pebbles or coarse sand. This group is probably extremely rare in the coastal plain (we have never found it in the College Woods streams). At Yorktown it was found exclusively in a very limited area at Washington Springs, extending from the origin of the springs through a short section of the flow formed by the three main springs combined. This is the only area we sampled where the type of substrate apparently required by this group for case-building is found. We did not find it in any other area, and therefore its absence in the DEQ collections at Baptist Run is consistent with our findings.

Chironomidae are an extremely widespread group, occurring in very diverse habitats. Most of the ones we found were either in sediment samples or in loosely-constructed cases attached to sticks. A few Chironomids occurred in DEQ collections, but as with the Limnephilidae the collecting method may not have been ideal for capturing this group.

The remaining 31 families in total accounted for only about 19% of the organisms (Table 6); this is similar to DEQ's data where 36 families accounted for about 20% of the individuals in their samples.

Our total number of 39 families collected is similar to DEQ's 40 families. However, the listings are not identical. Although the more common groups are in both samples (except for the Glossosomatidae, which is unique to Washington Springs as described above), not unexpectedly there are some differences among rarer groups, probably due in some cases to chance and in others to variation in collecting methods or type of habitat available. The following DEQ groups were not found in our samples: Hydrobiidae, Tubificidae, Crangonyctidae, Perlodidae, Veliidae, Leptoceridae, Rhyacophilidae, Leptophlebiidae, Pyralidae, Dryopidae, Elmidae, Dixidae, Empididae, and Stratiomyidae. The following were found in our collections but not DEQ's: Parachordodidae, Lymnaeidae, Corixidae, Mesoveliidae, Nepidae, Notonectidae, Glossosomatidae, Libellulidae, Dytiscidae, Gyrinidae, and Chaoboridae. Overall, DEQ sampling at Baptist Run plus our work resulted in the collection of 53 families, as listed in Table 7.

There were differences among our six sites in the total number of families found, with 13 and 14 in Ballard Creek and Great Run, respectively, and 21-26 in the other four areas (Table 5). The relatively low number in Ballard Creek and Great Run might raise concern regarding possible impairment. However, we note that all six communities were very similar in regard to their major components; all included individuals from the families listed in Table 6 (except Glossosomatidae). Given that all contained groups thought to be associated with good water quality, we believe the differences probably are due in large part to chance effects of sampling small populations. In any case, much more extensive work would be necessary to determine if there is in fact a real difference.

We believe therefore that for all sampling areas the interpretation of these results regarding water quality would be essentially identical to that already described based on DEQ's results at Baptist Run, and need not be repeated here. Broadly, freshwater stream community structure appears to be similar to that of habitats thought to be as undisturbed as any remaining in this general area of Virginia. The Battlefield is probably one of the largest areas for which this statement can be made.

The uniqueness of the Battlefield area can be further understood by considering, once again, *G. pseudolimnaeus.* We believe that historically this species was probably widespread in the Peninsula region, and perhaps over a much larger geographic areas as well. Now it exists primarily in scattered, isolated populations in small habitats that have escaped disturbance. For example, it was probably present at one time throughout the freshwater portions of College Creek and its tributaries in the Williamsburg area. Now it is absent from the dammed portion of the stream that has become a polluted lake (Lake Matoaka), from the remaining freshwater stream below the lake, and from the small streams flowing into the lake on the developed side of the basin. It persists only in a few small streams in the protected College Woods. Even in these, it may not be subject to completely "natural" conditions, because the populations in these streams are completely isolated from each other, with no possibility of gene flow among them via reproduction. Papermill Creek, also in the Williamsburg area, is significantly disturbed but, consistent with our hypotheses described earlier, has *G. fasciatus* in some areas. *G. pseudolimnaeus* now exists only in some very small protected seep areas flowing into the creek. In contrast, at the Battlefield, *G. pseudolimnaeus* exists in extensive, interconnected populations that span a wide variety of habitats, from very small seeps to flows significantly larger than any it is currently known from in other areas, and with substrates ranging from fairly silty to sand/pebble (see Additional Findings #1 below). At present, we know of no other area that provides this degree of habitat range involving continuously-distributed populations of this species. Adding further interest to the situation at the Battlefield is the fact that there are actually two large but presumably separate populations involved, because those *G. pseudolimnaeus* in the James River drainage are isolated from those in the York River drainage.

The Glossosomatidae are another group that may be of special interest. In contrast to G. *pseudolimnaeus,* these caddisflies appear to exist in a very small population restricted to a single location (Upper Washington Springs, as described) . As noted earlier, we have never found this family even in the College Woods, and Mr. Silvia of DEQ reports that he has never seen it in the coastal plain. As an "EPT" organism with the lowest possible tolerance value (0), it is undoubtedly rare in this area because of both natural habitat requirements and the impaired conditions in many streams.

Overall, our findings suggest that the Battlefield area is an important preserve for coastal plain stream macrobenthos.

Additional Findings and Considerations

A number of miscellaneous additional observations and considerations are relevant to our general purposes of inventory and habitat-quality assessment, and to recommendations or future work, as follows.

1) Collection of amphipods in areas other than those described above confirmed that *G. pseudolimnaeus* is widespread throughout the area. Specifically, it occurs at all the following sites (see earlier site descriptions and the map in Figure 1): #l, 4, 5, 6, 7, 8, 9, 10, 11, 12, 16, 17, 18, 19, and 20. In all of these locations except #6, it appeared to be the only amphipod species present, based on identification of at least 100 individuals collected at random. At site 6 (Beaverdam Creek at the tour road crossing), a few *G. fasciatus* were found with the G. *pseudolimnaeus*.

2) *G. fasciatus* were found not only at Site 6, but also about .7 km downstream from this location, where no *G. pseudolimnaeus* were found. Thus, there appears to be a population gradient between the two species in Beaverdam Creek, with a downstream transition from *G. pseudolimnaeus* to *G. fasciatus* beginning at about Site 6. The implications of this species change are unclear. As noted earlier, in some cases the absence of *G. pseudolimnaeus* in combination with the presence of *G. fasciatus* appears to be associated with moderately-degraded conditions. However, there may be natural changes that lead to this transition. For example, the lower area of Beaverdam Creek appears to have a generally siltier substrate with slower current flow than is the case at Site 6 and above; this may be a situation better-tolerated by *G. fasciatus*. Further work in this area to characterize water quality and general habitat conditions would be valuable.

G. fasciatus was also the only species found in Wormley Pond, at Sites 2 and 3, although *G. pseudolimnaeus* was abundant in the tributaries of the pond (Sites 1, 4, 5). This is consistent with our observations in the College Woods, where *G. fasciatus* but not *G. pseudolimnaeus* occurs in highly-eutrophic Lake Matoaka, even though *G. pseudolimnaeus* is abundant in undisturbed tributary streams. At present, the mechanisms that underlie these patterns are not known.

3) Another amphipod species is also present at the Battlefield: *Synurella chamberlaini* in the family Crangonyctidae[3]. We found a few of these individuals at Sites 13, 14, and 15 in the upper portion of the Great Run drainage. No other amphipods were present in this area, probably because flow is intermittent. The small tributary of Great Run (Site 14) at times was completely dry, and Great Run proper was sometimes reduced to small isolated pools from Site 13 downstream to Site 16.

Almost nothing is known of the specific habitat requirements of *S. chamberlaini*, but on the W&M campus we have found it in two general situations: undisturbed areas where the water is too dilute to allow other amphipods to survive, and highly disturbed areas that suffer from various problems which prevent other amphipods from occurring. Our hypothesis, for which we have no further supporting information, is that *S. chamberlaini* is competitively inferior to the two *Gammarus* species, but can tolerate more extreme conditions (whether natural or human caused) and so is found only in such areas where the other species are unable to survive. The presence of this species in the intermittent flow areas of upper Great Run, including the small tributary where the water is very dilute (Site #14, conductivity = 30 µmhos) is apparently typical, but there is no information on how this species is able to survive in, or recolonize, such areas.

4) Other areas also dried up intermittently during the course of our study. Some of these contained abundant benthos, particularly G. *pseudolimnaeus;* this raises questions about the mechanisms by which individuals of this species do, or do not, survive during small-scale drought conditions, and mechanisms by which the areas are recolonized. The two areas most notable in this regard are Site 4 and Site 7. Site 4 is a small stream flowing from the southwest into Wormley Pond; Site 7 is a spring-fed flow emptying into Beaverdam Creek. At Site 4, water was frequently present as far upstream as the immediate vicinity of Cook Rd., with abundant amphipods in this area; at other times, however, water was almost completely absent except for a small flow that began within 50 m of Wormley Pond. At Site 7 flow along the 200 m distance from the spring to Beaverdam Creek varied at times from continuous to completely absent. In both areas amphipods were abundant shortly after flows returned. There was no evidence of amphipods surviving by burrowing into the substrate, so colonization presumably occurred from the pool of individuals in the small amount of water remaining above Wormley Pond at Site 4, and from Beaverdam Creek at Site 7. However, these observations raise interesting questions for further study regarding amphipod behavior and adaptations in temporary-flow environments.

5) The Battlefield area could be very valuable in research aimed at answering other questions about amphipods. For example, a more-detailed analysis of the habitats where G. *pseudolimnaeus, G. fasciatus,* and *S. chamberlaini* occur would be important in clarifying the extent to which each can be used by its presence/absence to characterize stream impairment, as discussed earlier. Another valuable project would involve the determination of whether the apparent *G. pseudolimnaeus* at the Battlefield (see footnote #1) are in fact the same species as those from other areas of southeastern Virginia, or those from the Great Lakes area. This could be done by laboratory studies involving the success of mating and offspring production between

---

[3] Although we did not find this family in our six main sampling areas, a few individuals (not identified to species) are reported in the DEQ data for Baptist Run. This family is therefore already included among the 53 total families known for the area, as listed in Table 7.

males and females from different areas; we have already begun some preliminary work in this regard.

6) This study, by adding further to the knowledge of natural benthos assemblages in coastal plain streams, contributes broadly to the interpretation of biomonitoring data. A recent important trend in biomonitoring work has been the involvement of citizen groups, who may receive assistance and training from organizations such as the Izaak Walton League or Save Our Streams (SOS). Currently, for example, a citizens group interested in Powhatan Creek near Williamsburg has consulted with SOS. Literature and procedures from this organization, however, emphasize locating, and then collecting in, gravel or similar substrates, with special emphasis on the importance of EPT organisms as indicators of good quality. We have already begun to discuss with a representative of SOS our findings in the Battlefield and other areas, to advise them of the need for a different model in this area.

7) All of the work described here focuses on streams. Undoubtedly the list of freshwater macrobenthos is significantly longer than that reported here, involving not only very rare stream groups but those more typical of standing waters. The latter would include Wormley Pond, as well as the swamp and freshwater marsh habitat occurring in various areas. Continued collecting specifically for inventory purposes would be valuable.

8) As the final draft of this report was being prepared, an important paper involving coastal plain macroinvertebrates appeared in the *Journal of the North American Benthological Society*:

Maxted, J., M. Barbour, J. Gerritsen, V. Poretti, N. Primrose, A. Silvia, D. Penrose, and R. Renfrow. 2000. Assessment framework for mid-Atlantic coastal plain streams using benthic macroinvertebrates. JNABS 19 (1) 128-144.

This paper integrates water quality and macrobenthic data from six coastal plain states and, among other things, provides extremely valuable information on the most appropriate metrics (formulas for quantifying sample data) for discriminating levels of impairment. No data from the Battlefield area were included in this report, and differences in the methods and purposes between our work described here and that in the paper prevent direct comparisons. However, further collecting in the Battlefield area using the exact procedures described in the paper would be valuable, particularly if the results and suggestions in the paper become generally accepted.

Recommendations

In light of the fact that our biomonitoring work found no apparent significant impairment, current management practices at the Battlefield appear to be satisfactory. This conclusion must be tempered by the fact that historical biomonitoring information from this area is lacking, and there remains significant uncertainty about community structure in relation to varying natural habitat conditions in the coastal plain. Thus the true relation between current conditions in the macrobenthic community and those in an absolutely pristine situation cannot be determined with certainty. But we find no obvious problems in any of the six areas sampled, and therefore do not suggest any specific corrective actions that need to be taken. Of course, many of the streams include a drainage area outside the Battlefield's boundaries, and therefore vigilance regarding activities in these areas will be important.

Given the apparent value of the Battlefield area as a preserve for coastal plain stream benthos, a thorough understanding of the physical/chemical conditions would be valuable. We therefore recommend development of a continuous monitoring program that would provide year-round information on a wide variety of physical parameters and chemical constituents. This would provide not only baseline information that would be important in assessing any future changes, but also clues to the factors affecting distribution patterns of benthos that would be very helpful in designing research work.

Acknowledgements

We especially thank Tony Silvia of the Virginia Department of Environmental Quality for providing the Baptist Run data reported and analyzed here. Several students at the College of William & Mary assisted with various aspects of this work, including Katherine Staron, Meredith Bowden, and Summer Gibbs.

Gastropoda (snails)
- Mesogastropoda: *Hydrobiidae (3)*
- Limnophila: *Physidae (8)*

Bivalvia (clams)
- Unionoida: *Sphaeriidae (8)*

Oligochaeta (worms)
- Lumbriculida: *Lumbriculidae (8)*
- Haplotaxida: *Tubificidae (10)*

Hirudinea (leeches and related)
- Branchiobdellida (crayfish worms): *Branchiobdellidae*

Crustacea (crustaceans)
- Amphipoda (amphipods, scuds): *Crangonyctidae, Gammaridae (4)*
- Isopoda (aquatic sow bugs): *Asellidae (8)*
- Decapoda (crayfish, prawns): *Cambaridae (5), Palaemonidae (5)*

Insecta (insects)
- Plecoptera (stoneflies): *Nemouridae (2), Perlodidae (2)*
- Hemiptera (true bugs): *Gerridae (8), Veliidae (6)*
- Trichoptera (caddisflies): *Hydropsychidae (6), Leptoceridae (4), Limnephilidae (4) Rhyacophilidae (0)*
- Ephemeroptera (mayflies): *Baetidae (4), Heptageniidae (4), Leptophlebiidae (2)*
- Odonata (dragonflies): *Aeshnidae (3), Cordulegastridae (3), Gomphidae (1)*
- Odonata (damselflies): *Calopterygiidae (5)*
- Lepidoptera (moths): *Pyralidae (5)*
- Coleoptera (beetles): *Dryopidae (5), Elmidae (4), Hydrophilidae (5)*
- Megaloptera (dobsonflies): *Corydalidae (5)*
- Diptera (flies): *Ceratopogonidae* (6), *Chironomidae*(6-9), *Culicidae* (8), *Dixidae* (1), *Empididae* (6), *Simuliidae* (6), *Stratiomyidae* (7), *Tabanidae* (6), *Tipulidae* (3)

Table 1: Families of macrobenthos collected in Baptist Run *1993-1998* by Department of Environmental Quality. Major groupings are by taxonomic class, subdivided into orders; family names are italicized. Numbers indicate the tolerance value assigned to the given family (no values have been established for the Branchiobdellidae and Crangonyctidae).

	Total Number	Percent	No./Sample
G. pseudolimnaeus	693	53	63.0
Physidae	149	11	13.6
Sphaeriidae	135	10	12.3
Calopterygiidae	57	4	5.2
Gomphidae	25	2	2.3
All others (36 families)	261	20	23.7 (= 0.7 indiv/family/sample)

Table 2: Community composition (by numbers collected) at the Baptist Run site sampled by DEQ.

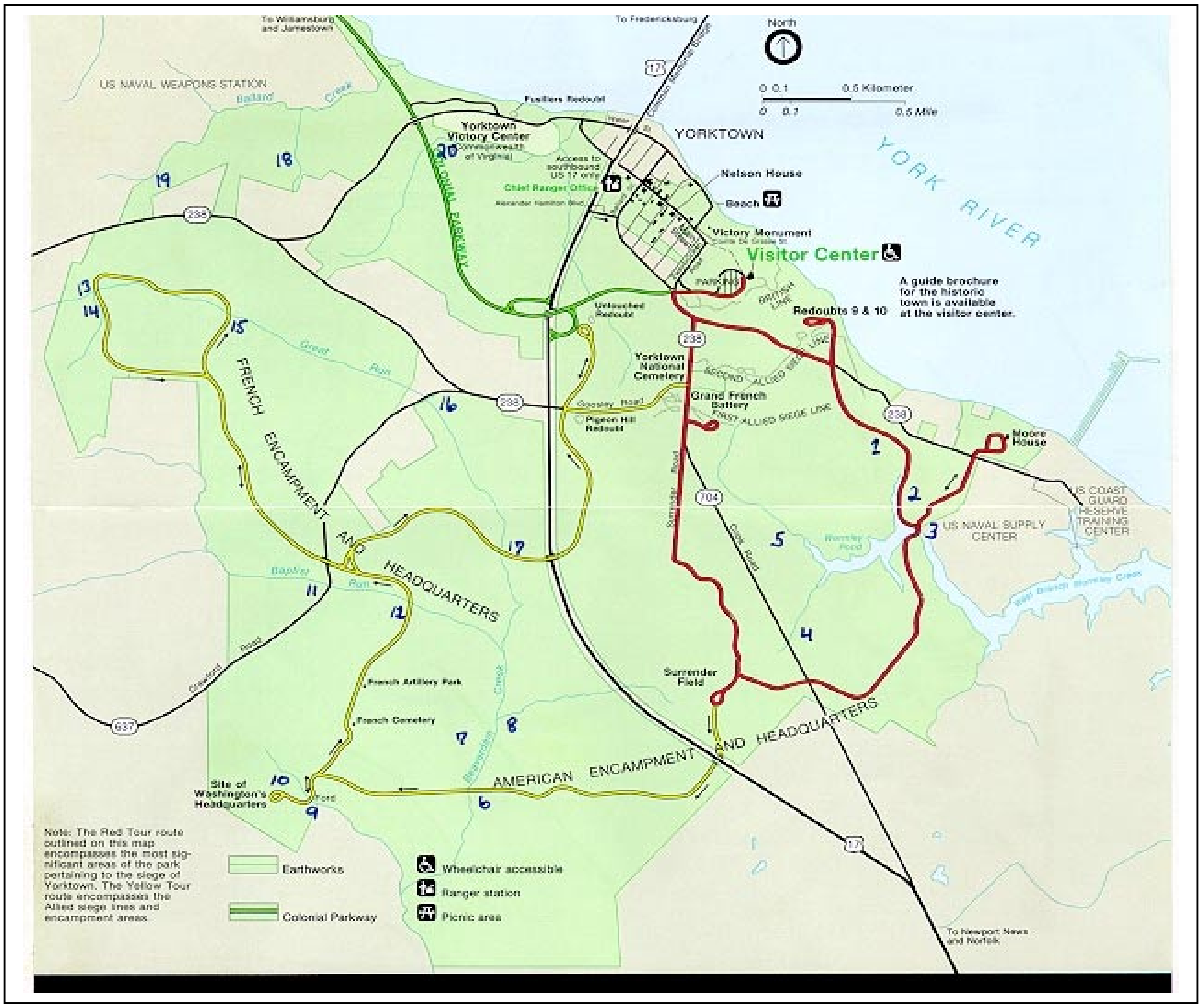

Figure 1: Sites at Yorktown Battlefield used for general observations and basic chemical survey (see text and Table 3 for descriptions and results; note "red" and "yellow" tour roads used in descriptions).

Site	Temp (^{o}C)	Oxygen (mg/L, % sat)	pH	Conductivity (μmhos)
1	11.0	5.2, 47%	7.7	500
2	11.5	8.3, 75%	7.6	290
3	11.5	10.0, 91 %	7.5	270
4	14.0	7.5, 72%	7.4	470
5	14.0	9.4, 90%	7.1	455
6	12.0	8.9, 82%	8.0	240
7	14.0	3.0, 29%	7.1	340
8	13.5	7.0, 67%	7.8	220
9	14.0	7.8, 75%	7.4	330
10	15.0	3.1, 31%	7.1	300
11	12.5	8.8, 82%	7.7	350
12	12.5	8.5, 79%	7.7	330
13	13.0	8.4, 79%	7.9	110
14	13.5	7.5, 71%	6.5	30
15	13.5	8.0, 76%	7.9	150
16	14.0	7.0, 67%	7.9	235
17	14.0	8.5, 82%	7.9	240
18	13.0	5.7, 54%	7.6	445
19	13.0	8.8, 83%	7.7	425
20	14.5	9.0, 86%	7.9	330

Table 3: Temperature, oxygen, and conductivity values for twenty sites in the Yorktown Battlefield area, sampled during March 1997. See text and Figure 1 for site locations and descriptions.

Site	Temp (ºC)	O_2 (mg/L)	pH	Cond (µmhos)	Ca (mg/l)	TotHd (mg/l)	Alk (mg/l)	Cl (mg/l)	SO_4 (mg/l)	SiO_2 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)
WS	15.5	8.9	7.4	320	207	215	182	4.2	7	4.1	0.4	.01
BR	16.0	8.8	7.9	270	172	180	159	6.2	3	6.1	0.8	.02
GR	16.0	8.5	8.0	280	170	176	157	7.3	6	12.3	0.6	.02
BvC	16.5	8.9	7.6	295	175	181	150	4.4	10	6.2	0.7	.01
BlC	15.0	8.5	7.8	410	280	281	249	3.5	23	11.0	1.0	.10
WC	15.0	9.0	8.0	435	263	265	165	5.2	19	9.8	0.9	.01

Table 4: Chemical data for six sites comprising the primary collecting areas for macrobenthos. Site abbreviations: WS = Washington Springs, BR = Baptist Run, GR = Great Run, BvC = Beaverdam Creek, BlC = Ballard Creek, WC = Wormley Creek. Other abbreviations: Temp = Temperature, Cond = Conductivity, TotHd = Total Hardness, Alk = Alkalinity, Calcium, Total Hardness, and Alkalinity are all expressed as mg/l $CaCO_3$.

Family/(Tol. Val)	Site WS	BR	GR	BvC	BIC	WC
Planariidae (8)	57					2
Parachordodidae (n/a)	1	3		1		
Lymnaeidae (7)	2			2		
Physidae (8)	85	46	24	43	28	45
Sphaeriidae (8)	12	7	4	28	20	8
Lumbriculidae (8)		4	15	3	2	
Branchiobdellidae (5)	27		5	8		
Gammaridae (4)	206	163	156	186	184	159
Asellidae (8)				5		8
Cambaridae (5)	7	4	3	4		1
Palaemonidae (5)		1		8		
Perlodidae (2)	1					
Corixidae (5)				1	7	4
Gerridae (8)	3					5
Mesoveliidae (6)	12	11	6	18		
Nepidae (6)				1		
Notonectidae (5)		3		2		10
Glossosomatidae (0)	63					
Hydropsychidae (6)		2		2	6	
Limnephilidae (4)	14	9	13	18	6	8
Baetidae (4)	6					
Heptageniidae (4)	12	6		7		2
Aeshnidae (3)		3				7
Cordulegastridae (3)		1				
Gomphidae (1)	2	25	23	38	2	1
Libellulidae (9)						2
Calopterygiidae (5)	2	18	6	39	3	1
Dytiscidae (5)				1		10
Gyrinidae (4)				5		17
Hydrophilidae (5)		2				
Corydalidae (5)	2	2	4	1	2	7
Sialidae (4)	1	1	2	1	3	1
Ceratopogonidae (6)						3
Chaoboridae (7)						2
Chironomidae (6-9)	3	7	25	6	2	12
Culicidae (8)						3
Simuliidae (6)	21					
Tabanidae (6)		2	5	2		1
Tipulidae (3)	2			2	2	
Total Number	**541**	**320**	**291**	**432**	**267**	**319**
Total Taxa	**22**	**21**	**14**	**26**	**13**	**24**
% G. pseudolimnaeus	**38%**	**51%**	**54%**	**43%**	**69%**	**50%**
% Physidae	**16%**	**14%**	**8%**	**10%**	**10%**	**14%**

Table 5: Numbers of individuals in families collected at six sample sites at Yorktown Battlefield. Number after family name indicates tolerance value. Site abbreviations are as in Table 4.

	Total Number	Percent
G. pseudolimnaeus	1054	48.6
Physidae	271	12.5
Gomphidae	91	4.2
Sphaeriidae	79	3.6
Calopterygiidae	69	3.2
Limnephilidae	68	3.1
Glossosomatidae	63	2.9
Chironomidae	55	2.5
All others (31 families)	420	19.4

Table 6: Overall combined community composition (by numbers collected) for six sample areas at Yorktown Battlefield.

Turbellaria (flatworms)
- Tricladida: *Planariidae*

Gordioida (horsehair worms)
- Gordioidea: *Parachordodidae*

Gastropoda (snails)
- Mesogastropoda: *Hydrobiidae*
- Limnophila: *Lymnaeidae, Physidae*

Bivalvia (clams)
- Unionoida: *Sphaeriidae*

Oligochaeta (worms)
- Lumbriculida: *Lumbriculidae*
- Haplotaxida: *Tubificidae*

Hirudinea (leeches and related)
- Branchiobdellida (crayfish worms): *Branchiobdellidae*

Crustacea (crustaceans)
- Amphipoda (amphipods, scuds): *Crangonyctidae, Gammaridae*
- Isopoda (aquatic sow bugs): *Asellidae*
- Decapoda (crayfish, prawns): *Cambaridae, Palaemonidae*

Insecta (insects)
- Plecoptera (stoneflies): *Nemouridae, Perlodidae*
- Hemiptera (true bugs): *Corixidae, Gerridae, Mesoveliidae, Nepidae, Notonectidae, Veliidae*
- Trichoptera (caddisflies): *Glossosomatidae, Hydropsychidae, Leptoceridae, Limnephilidae, Rhyacophilidae*
- Ephemeroptera (mayflies): *Baetidae, Heptageniidae, Leptophlebiidae*
- Odonata (dragonflies): *Aeshnidae, Cordulegastridae, Gomphidae, Libellulidae*
- Odonata (damselflies): *Calopterygiidae*
- Lepidoptera (moths): *Pyralidae*
- Coleoptera (beetles): *Dryopidae, Dytiscidae, Elmidae, Gyrinidae, Hydrophilidae*
- Megaloptera (dobsonflies): *Corydalidae*
- Megaloptera (alderflies): *Sialidae*
- Diptera (flies): *Ceratopogonidae, Chaoboridae, Chironomidae, Culicidae, Dixidae, Empididae, Simuliidae, Stratiomyidae, Tabanidae, Tipulidae*

Table 7: Complete listing of the 53 families of macrobenthos collected in streams at Yorktown Battlefield, combining DEQ data for Baptist Run with the additional information described in this report. Major groupings are by class, subdivided into orders; family names are italicized.